Endovascular management of isolated iliac artery aneurysms

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Objective: **We reviewed our experience with endovascular treatment of isolated iliac artery aneurysms (IAAs).**

Methods: **Medical records for consecutive patients undergoing endovascular IAA repair from 1995 to 2004 were reviewed. Computed tomography (CT) angiograms were used to assess IAA location, size, and presence of endoleaks after endovascular repair. Rates of primary patency and freedom from secondary interventions were estimated using the Kaplan-Meier life-table method.**

Results: **From July 1995 to November 2004, 45 patients (42 men), with a mean age of 75 years, underwent endovascular repair of 61 isolated IAAs: 41 common iliac, 19 internal iliac, and one external iliac. Five patients (11%) were symptomatic, although none presented with acute rupture. The mean preoperative IAA diameter was 4.2 ± 1.7 cm. Fifteen patients (33%) had prior open abdominal aortic aneurysm repair. Local or regional anesthesia was used in 28 cases (62%). Thirty-four patients (75%) were treated with unilateral iliac stent-grafts, eight (18%) with bifurcated aortic stent-grafts, and three (7%) with coil embolization alone. Perioperative major complications included one early graft thrombosis that eventually required conversion to open repair and one groin hematoma that required operative evacuation. On follow-up, late complications included one additional graft thrombosis and one late death after amputation. No late ruptures occurred after endovascular repair, with a mean follow-up of 22 months (range, 0 to 60 months). The mean postoperative length of stay was 1.3 ± 1.0 days. On postoperative CT scans obtained at 1, 6, 12, 24, and 36 months, aneurysm shrinkage was noted in 18%, 29%, 57%, 67%, and 83% of IAAs, respectively, compared with the baseline diameter. One hypogastric aneurysm enlarged in the presence of a later identified type II endoleak. Five endoleaks were noted (4 type II, 1 indeterminate) at 1 month, with four other endoleaks (1 type II, 1 type III, 2 indeterminate) identified on later CT scans. At 2 years, primary patency was 95%, and freedom from secondary interventions was 88%.**

Conclusions: **Endovascular repair of isolated IAAs appears safe and effective, with initial results similar to those after endovascular abdominal aortic aneurysm repair. (J Vasc Surg 2006;44:29-37.)**

Although almost all iliac artery aneurysms (IAAs) occur in the setting of coexisting abdominal aortic aneurysms (AAAs),[1] isolated IAAs occurring in the absence of AAA are rare, accounting for only 2% of all intra-abdominal aneurysms and 0.03% of patients in a recent large autopsy series.[2,3] Most IAAs are asymptomatic, but patients may present with rupture, distal embolization, thrombosis, and symptoms of visceral or neurologic compression.

Ruptured IAAs are associated with significant operative mortality as high as 33% to 50% in some reports.[2] Preventing the mortality associated with IAAs hinges on identifying those patients with significant risk of rupture for prophylactic repair. Although no prospective natural history data exist, IAA diameter has been used most commonly as a surrogate for rupture risk, with repair recommended in those with IAAs >3 to 4 cm.[4]

Surgical treatment traditionally consists of open excision, ligation, or endoaneurysmorrhaphy and has been considered the gold standard. However, this is often technically challenging given the pelvic location of iliac aneurysms and the frequent history of prior AAA repair. This may account for the higher mortality (10%) reported in one large series[2] of elective common and hypogastric IAA repairs compared with AAA repair, although some more recent reports suggest improving results.[1,4]

Recently, endovascular repair of isolated IAAs has emerged as an alternative to open repair. Performed by using a combination of branch-vessel coil embolization and stent-grafting, this technique has the potential to reduce perioperative morbidity and mortality, especially in high-risk patients. In this study, we report our initial experience with endovascular treatment of isolated IAAs.

METHODS

Medical records for consecutive patients undergoing endovascular IAA repair from 1995 to 2004 were reviewed. No pseudoaneurysms or mycotic aneurysms were included, leaving only true atherosclerotic aneurysms for consideration. Isolated IAAs were defined as either single or multiple aneurysms located only within the common, internal, or external iliac arteries. Patients with aortic diameters >3.5 cm were excluded because of concomitant AAA, but not those with prior open AAA repair.

Patient characteristics, comorbidities, as well as presentation and symptoms were reviewed. In all cases, computed tomography (CT) with intravenous contrast was used to

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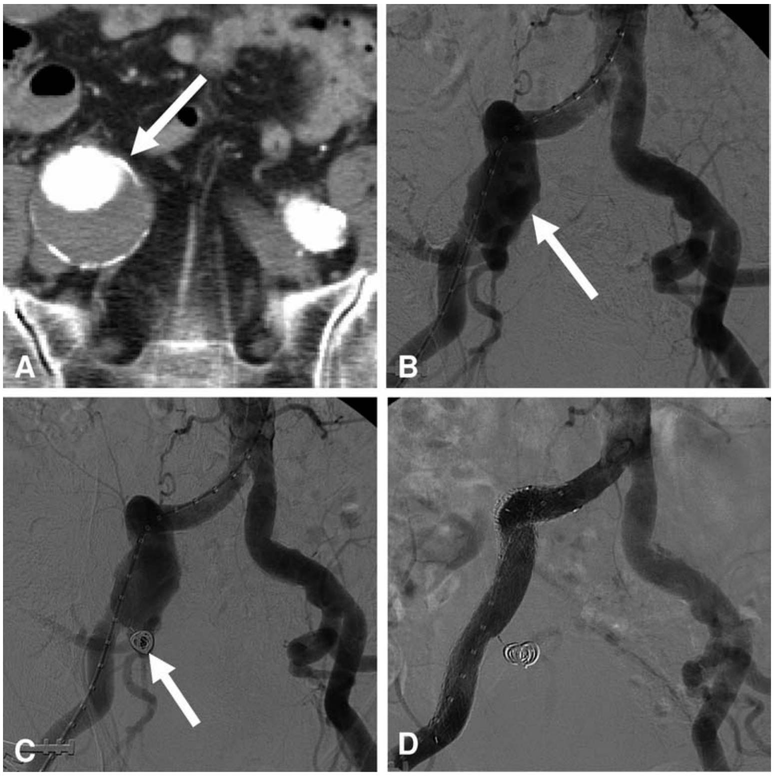

Fig 1. A, Preoperative computed tomography angiography of an 83-year-old patient with a 4.5-cm right common iliac artery aneurysm *(arrow)*. **B,** Initial angiogram of right common iliac artery aneurysm *(arrow)*. **C,** Coil embolization *(arrow)* of a right internal iliac artery. **D,** Successful exclusion of right common iliac artery aneurysm after stent-graft deployment.

assess IAA location and diameter and to plan endovascular repair, if appropriate. Preoperative angiography was used only in selective cases at the discretion of the surgeon or referring physician. Iliac aneurysm diameter was measured in the short-axis by CT in an effort to minimize the error associated with measurements of aneurysm diameter in long-axis along the length of the blood vessel, as it often courses transversely through serial images.

Operative data were recorded, including type of repair, anesthetic technique, procedural time, estimated blood loss, and intraoperative complications. In the case of endovascular repair, vascular access technique (percutaneous vs femoral cut-down), graft configuration (unilateral vs bifurcated stent-graft), and need for hypogastric coil embolization were noted.

At the time of endovascular repair, ipsilateral or bilateral femoral arterial access was obtained, either percutaneously or by cut-down, based on the surgeon's preference, type of stent-graft, and availability of appropriate closure devices. Depending on the type of stent-graft chosen, 10F to 26F sheaths were used for arterial access. Contralateral access was obtained when bifurcated grafts were used or when necessary to control the deployment of unilateral grafts.

All patients initially underwent intraoperative aortic and pelvic angiography to define the IAA and size the stent-graft (Fig 1, *B*). Angiograms with marker catheters at the time of stent-graft repair were used to confirm estimates of appropriate device lengths as determined by preoperative CT angiography (CTA). Iliac artery and stent-graft diameters were based on measurements made by preoperative CTA.

In the case of isolated common iliac aneurysms, if a length $\geq$1.5 cm of nonaneurysmal artery ($<$1.5 cm in diameter) was present proximally and distally for stent-graft fixation and sealing, the stent-graft was simply deployed across the IAA for exclusion, preserving the internal iliac artery. However, if the aneurysm involved the origin of the internal iliac artery, or the length of adjacent distal nonaneurysmal iliac artery was inadequate ($<$1.5 cm), the origin of the internal iliac artery was coil-embolized and covered by the stent-graft with extension to the external iliac artery (Fig 1, *C* and *D*).

In cases of bilateral common IAAs or common IAAs without adequate proximal necks ($\leq$1.5 cm), bifurcated aortoiliac stent-grafts were used, most frequently preserving at least one internal iliac artery. In the case of internal IAAs, the branches (anterior and posterior divisions) of the internal iliac artery were individually coil-embolized. When feasible, a stent-graft was also placed across the origin of the internal iliac artery to ensure aneurysm exclusion. In cases where open femoral exposure was performed, iliac and femoral circumflex collaterals to the pelvis were preserved at the time of stent-graft repair.

Details of the hospital course were reviewed, including length of stay and any early postoperative complications. Also documented were any late complications, including IAA rupture, graft thrombosis, and death. At follow-up, patients were routinely asked about the presence of claudication. All patients who underwent endovascular repair were seen at 1 month postoperatively and then yearly in uncomplicated cases, with CTA performed at each visit to document changes in IAA diameter and the presence of any endoleaks. Although this is currently our standard follow-up protocol, some patients also had a 6-month follow-up early in our experience with aortoiliac stent-grafting.

A change in IAA short-axis diameter of ≥5 mm was defined as significant. In patients with aneurysm sac enlargement or new endoleaks requiring treatment, more frequent follow-up was performed at the discretion of the surgeon. The need for any secondary interventions was noted (eg, for endoleak or limb thrombosis). Rates of primary patency and freedom from secondary interventions were estimated using the Kaplan-Meier life-table method. Categoric variables were compared with the Fisher's exact test, and means were compared using the Student's t test, as appropriate.

RESULTS

Patient and IAA characteristics. From July 1995 to November 2004, 45 patients (42 men), with a mean age of 75 years, underwent endovascular repair of 61 IAAs. Five patients (11%) were symptomatic, but none presented with acute rupture. Although one patient underwent endovascular iliac aneurysm repair in 1995 with a custom-made device, commercially available stent-graft components fueled a rapid rise in the number of endovascular IAA repairs performed since 2000 (n = 39).

Among the 45 endovascular cases, most patients had isolated common IAAs (23/45 unilateral, 3/45 bilateral), common IAAs extending into the internal iliac artery (9/45), or common IAAs extending into the external iliac artery (1/45). Only 20% (9/45) of IAAs involved the hypogastric artery alone. The mean preoperative IAA diameter was 4.2 ± 1.7 cm (range, 2.7 to 12 cm). Among those with common IAAs, mean diameter was 3.9 ± 1.1 cm, and internal IAAs measured 4.9 ± 2.4 cm. Patient characteristics are summarized in Table I.

Fifteen patients (33%) had prior open AAA repair (tube grafts in 9, aortobiiliac in 4, aortobifemoral in 2). No patients managed by endovascular repair presented with rupture, but five patients (11%) were deemed to be symptomatic (abdominal pain in 3, buttock claudication in 2). Asymptomatic IAAs (40/45, 89%) were identified incidentally during evaluation and imaging of other nonvascular abdominal processes, as part of an "aneurysm survey" when peripheral lower extremity aneurysms were diagnosed, on follow-up after AAA repair, or during cardiac catheterization.

Table I. Clinical characteristics of patients undergoing iliac artery aneurysm endovascular repair

Characteristic	*Patients (n = 45) (%)*
Age (years)	75 ± 9
Male	42 (93)
Hypertension	35 (78)
Coronary artery disease	27 (60)
Congestive heart failure	4 (9)
Peripheral vascular occlusive disease	12 (22)
Hyperlipidemia	20 (44)
Diabetes	9 (20)
Chronic renal insufficiency	8 (18)
COPD	15 (33)
Tobacco use	30 (6)
Prior AAA repair	15 (33)
Symptomatic	5 (11)
Abdominal Pain	2 (4)
Claudication	2 (4)

COPD, chronic obstructive pulmonary disease; *AAA,* abdominal aortic aneurysm.

Imaging. Although all patients underwent CT with intravenous contrast before endovascular repair for planning and stent-graft sizing, in less than half of the patients (21/45, 47%) was preoperative diagnostic angiography done as a separate procedure. In fact, early in our experience, preoperative angiography was performed in 65% (15/23) of cases. In contrast, since October 2002, preoperative angiography was performed in only 32% (7/22) of cases (P = .04). In five of these latter cases, diagnostic angiography and ipsilateral internal iliac artery coil embolization were combined as one procedure, essentially staging the endovascular IAA repair with later stent-grafting.

Operative technique. Local or regional anesthesia was used in 28 cases (62%), and the remaining 17 (38%) had general anesthesia (Table II). A completely percutaneous approach was used in 12 cases (27%), and 33 (73%) of 45 repairs were approached with an open common femoral artery exposure.

Stent-grafts. Thirty-four patients (75%) were treated with a variety of unilateral iliac stent-grafts, eight (18%) with bifurcated aortic stent-grafts, and three (7%) with coil embolization alone. Two patients underwent IAA exclusion with aortouniiliac stent-grafts and femorofemoral crossover bypasses. Among the 34 patients treated with unilateral stent-grafts, 19 had isolated common IAAs, eight had isolated internal IAAs, six had mixed common IAAs/internal IAAs, and one patient had a mixed common IAA/external IAA. The eight patients treated with bifurcated stent-grafts included six with isolated common IAAs and two with mixed common IAA/internal IAA. The types of stent-grafts used are also detailed in Table II.

Internal iliac artery coil embolization. Thirty-five patients (78%) required internal iliac artery coil embolization as part of internal IAA treatment or as an adjunct to the exclusion of common IAAs. Of the three patients who underwent coil embolization alone without stent-grafting, two had prior aortobifemoral bypasses and required unilat-

Table II. Operative characteristics of patients undergoing endovascular iliac artery aneurysm repair

Characteristic	*Patients (n = 45) (%)*
Anesthesia	
General	17 (38)
Regional	9 (20)
Local	19 (42)
Vascular Access	
Percutaneous	12 (27)
Femoral cut-down	33 (73)
Need for inIA coil embolization	
No	10 (22)
Yes	35 (78)
Stent-graft	
Unilateral	34 (75)
Excluder limb	9
Wallgraft	18
AneuRx limb*	18
Other	3
Bifurcated	8 (18)
Excluder	4
AneuRx	3
Ancure†	1
None (coiled only)	3 (7)
Estimated blood loss (mean) (mL)	289 ± 201
Procedure time (mean) (min)	157 ± 57

inIA, Internal iliac artery.
*Medtronic, Minneapolis, Minn.
†Guidant, Indianapolis, Ind.

eral internal iliac artery embolization as well as external IA ligation/embolization to eliminate retrograde flow into common IAAs. The remaining patient underwent branch-vessel coil embolization of an internal IAA, with plans for staged stent-graft coverage of the hypogastric orifice, but did not return for subsequent follow-up.

The other eight isolated internal IAAs were treated with branch-vessel coil embolization and stent-graft placement. In two cases of internal IAA, the branches of the internal iliac artery were technically not accessible, and the internal IAA was simply packed before stent-grafting. Fifteen patients had common IAAs that required adjunctive orificial internal iliac artery coiling before exclusion with a stent-graft. Eight of nine other patients had combined common IAA/internal IAAs and were treated with branch-vessel embolization of the internal IAA with subsequent stent-graft exclusion of the common IAA. The remaining patient, with a prior aortofemoral bypass, was managed as described earlier.

Among the 10 patients (22%) that did not undergo ipsilateral internal iliac artery embolization, three had pre-existing internal iliac artery occlusions. Four patients with common IAAs had simple coverage of internal iliac arteries due to either pre-existing high-grade hypogastric orificial stenosis considered preocclusive or a technical inability to catheterize the internal iliac artery; exclusion was successful in all of these IAAs. Three patients had an adequate distal common iliac artery for stent-graft deployment, allowing complete preservation of the ipsilateral internal iliac artery.

Among the five patients who had *bilateral* common iliac aneurysm repair, three had bilateral internal iliac artery involvement (without internal IAAs). In one patient, a decision was made to coil the origins of both internals (in a staged manner) because both arteries were severely stenotic and diffusely diseased and contributed little to pelvic perfusion. In a second similar patient who had prior AAA and retroperitoneal dissection, after coiling the origin of one internal iliac artery, an attempt to operatively revascularize the other before endovascular aneurysm repair was aborted due to difficulty with exposure. The origin of the internal was simply covered by the stent-graft. Both patients did well without any postoperative symptoms of pelvic ischemia. A third patient underwent revascularization of one internal iliac artery with a bypass. A fourth patient had pre-existing bilateral internal iliac artery occlusion. The remaining patient with bilateral common iliac aneurysms had one internal iliac artery preserved at the time of stent-graft repair, as at least one adequate distal common iliac implantation site was available.

Early outcomes (<30 days). The mean postoperative length of stay was 1.3 ± 1.0 days. Perioperatively (≤30-day), no patients died, and major complications included one early graft thrombosis and one groin hematoma requiring operative evacuation. The former patient, who was 63 years old, had undergone prior open AAA repair and had subsequently developed bilateral common IAAs that were treated with bilateral stent-grafts (Wallgrafts, Boston Scientific/Medi-tech, Natick, Mass). On the fifth postoperative day, the patient was readmitted with severe bilateral lower extremity claudication, and at angiography was found to have a thrombosed left iliac artery stent-graft and a significant stenosis at the distal portion of the right iliac artery stent-graft. Open conversion to an aortobifemoral bypass was subsequently performed.

Late outcomes (>30 days). At a mean follow-up of 22 months (range, 0 to 60 months), no ruptures followed endovascular repair. Late stent-graft–associated complications (>30 days) included two episodes of graft thrombosis in a second patient at 6 and 9 months after IAA repair. This was attributed to recurrent kinking of the stent-graft despite thrombolysis and stenting during the initial episode and ultimately resulted in the only late death in our series secondary to pneumonia after lower extremity amputation. Both patients with stent-graft thrombosis had grafts extended to the external iliac arteries. Two-year primary patency was 95% on Kaplan-Meier life-table analysis (Fig 2).

Postoperative claudication. Nine (23%) of the 39 patients who required internal iliac artery coil embolization or coverage during stent-graft repair reported new-onset buttock claudication at the first postoperative visit (30 days). Among these, four patients reported complete or near-complete resolution of symptoms within ≤30 days of IAA repair, and three patients experienced persistent symptoms for 3 to 12 months. Two patients remained symptomatic at the 2-year follow-up. Among the nine patients with buttock claudication noted at the first follow-up visit, six

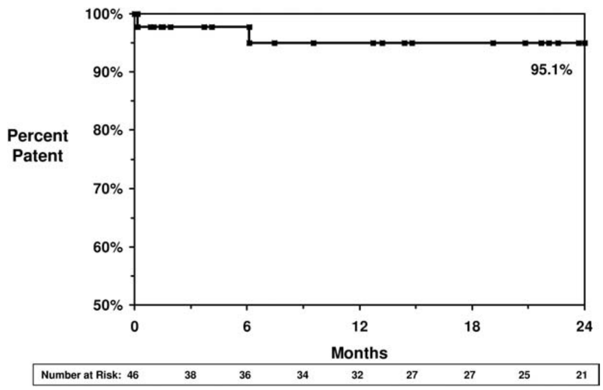

Fig 2. Two-year stent-graft primary patency in patients undergoing endovascular repair of isolated iliac artery aneurysms (Kaplan-Meier analysis).

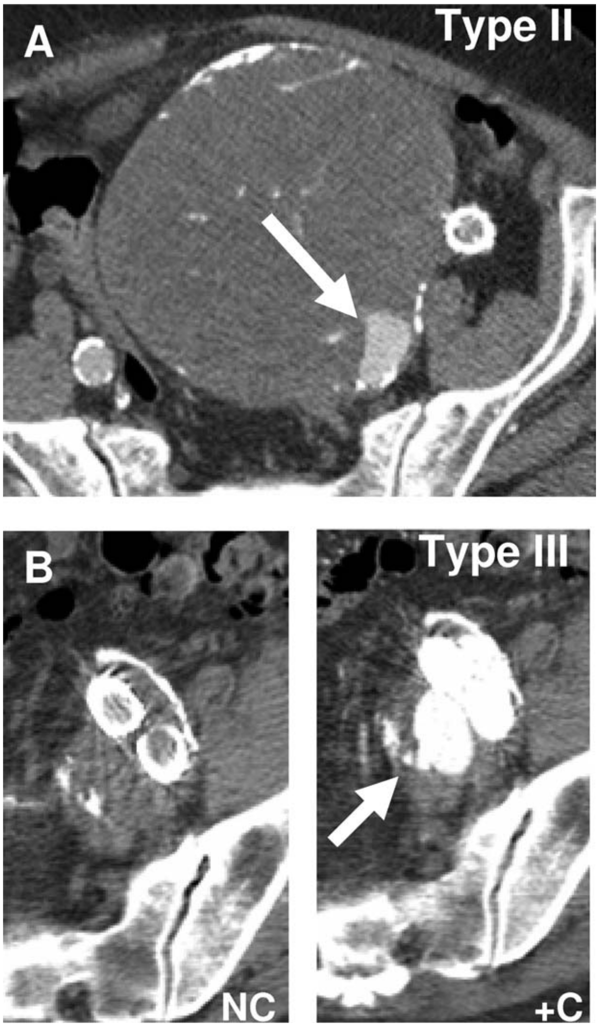

Fig 3. A, A Computed tomography angiogram angiogram (CTA> performed 6 months after endovascular repair of a 12-cm internal iliac artery aneurysm (IAA) shows a type II endoleak *(arrow)*. **B**, In a CTA performed 3 years after endovascular repair of a left common IAA/internal IAA with two overlapping stent-grafts, a disconnection is seen on noncontrast CT resulting in a type III endoleak *(arrow)*. *NC,* Noncontrast; *+C,* with contrast).

had common IAAs (main trunk of internal embolized), two had mixed common IAA/internal IAAs (internal iliac branch-vessels embolized), and one had an isolated internal IAA (internal iliac branch-vessels embolized). The contralateral internal iliac artery was already occluded in one of the patients treated for a common IAA who developed buttock claudication. The remaining eight patients had patent contralateral internal iliac arteries.

Endoleaks. Our standard protocol involves a follow-up CT scan at 1 month, but 12 of the 45 patients did not have available 1-month scans for our review. One patient underwent a duplex examination (without evidence of endoleak) as a result of severe chronic renal insufficiency and did not undergo CTA. Five other patients had follow-up imaging at other institutions that could not be retrieved for our evaluation. Six patients did not return for their initial 1-month scan but had subsequent scans (≥6 months) for our review.

Early endoleaks. Of the remaining 33 patients with available 1-month CT scans, five endoleaks (13%) were noted (4 type II, 1 indeterminate). Two of the four type II leaks identified on 1-month CT scans followed internal IAA repair, and two followed common IAA repair. None of these endoleaks were associated with increases in aneurysm diameter, and in fact, two patients with type II endoleaks had a significant decrease in diameter (>5 mm).

Late endoleaks. Four other endoleaks were identified on later CT scans (1 type II, 1 type III, 2 indeterminate). Of these, the type II endoleak (Fig 3, *A*) was treated with coil embolization in the setting of an enlarging internal IAA. This patient had undergone prior coil embolization and stent-grafting. On follow-up CT, he was noted to have persistent filling of an enlarging aneurysm. At the time of angiography, the source of the endoleak, branches of the ipsilateral deep femoral artery were coil-embolized. The patient with the type III endoleak (Fig 3, *B*) had undergone repair of a very tortuous common IAA/internal IAA 3 years earlier that used two overlapping Wallgrafts. A clear disconnection of the stent-grafts, with fracture of one of the stent-grafts, was noted on CTA and was treated with a third stent-graft that successfully bridged the disconnect. The three subtle indeterminate endoleaks, not easily classified as type I or II, were not associated with aneurysm enlargement and were observed.

IAA size change. Postoperative CT scans were available for review at 1, 6, 12, 24, and 36 months. Since several patients had multiple IAAs, each aneurysm (rather than patient) was tracked individually over time for significant changes in diameter (>5 mm). When compared with the preoperative IAA diameter, 18% (8/44) of IAAs demonstrated significant shrinkage at 1 month, 29% (4/14) at 6 months, 57% (13/23) at 12 months, 67% (10/15) at 24 months, and 87% (5/6) at 36 months. Of those IAAs with

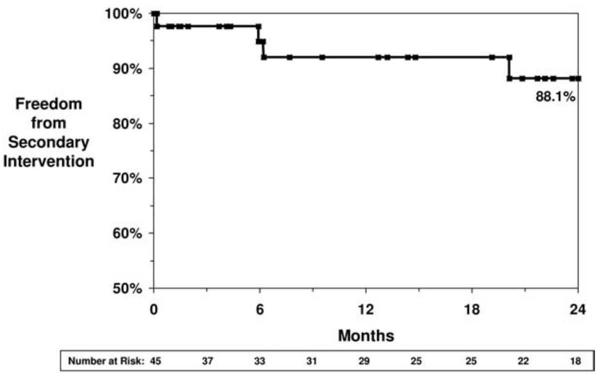

Fig 4. Two-year freedom from secondary interventions in patients undergoing endovascular repair of isolated iliac artery aneurysms (Kaplan-Meier analysis).

>5 mm decreases in diameter, the mean decrease in diameter at 1, 6, 12, 24, and 36 months, was 9, 13, 14, 16, and 20 mm, respectively.

Only one IAA (hypogastric) enlarged over the first year in the presence of a later identified type II endoleak. The remaining IAAs had no significant change in diameter at each of the time points. Three IAAs (2 internal IAAs, 1 common IAA) shrunk even in the presence of a type II endoleak.

Secondary interventions. Five patients (11%) required secondary interventions. As described previously, these included a single open conversion in one patient and thrombolysis with stenting before amputation in a second patient. One additional patient treated 2 years earlier for a common IAA experienced thrombosis of a contralateral common iliac stent that had been placed simultaneously at the aortic bifurcation opposite the stent-graft in a "kissing" manner. This was treated with a femorofemoral crossover bypass. Kaplan-Meier life-table method revealed an overall freedom from secondary intervention at 2 years of 88% (Fig 4).

DISCUSSION

Most IAAs occur in the setting of coexisting AAAs. Although we included IAAs that occurred after prior AAA repair, true isolated iliac aneurysms remain rare. Open IAA repair remains the standard therapy. It is associated with a higher mortality compared with routine AAA repair, however, and this may reflect the technical and anatomic challenges related to the pelvic location and prior aortic surgery. As a result of excellent early outcomes of endovascular AAA repair in properly selected patients,[5,6] we have applied a similar approach to IAAs with promising initial results. We elected to only treat intact IAAs by endovascular means. This was based on surgeon preference and the absence of an institutional protocol for the endovascular treatment of ruptured aortoiliac aneurysms. Currently, our experience with this technique in the setting of acute rupture is limited.

This series of endovascular IAA repairs represents one of the largest contemporary single-center studies using commercially available devices. Although those who have undergone prior AAA repair may not be considered to have true "isolated" IAAs by strict definitions, the endovascular approach in a patient whose only remaining aneurysm is an IAA may be similar from a technical standpoint in many cases, regardless of whether the infrarenal aorta has been replaced. Those patients who had prior AAA repair (electively or for rupture) but later developed IAAs warranting treatment, represented a significant proportion of patients overall (1/3 in this series) that may benefit from endovascular techniques. We therefore decided to include them in this analysis.

Clinical and anatomic characteristics of the patients are similar to those described in other IAA studies.[2] The group was almost entirely composed of men. This marked male predominance is characteristic of iliac aneurysms and has been described in several open and endovascular series.[1,2,4,7] The mean age of patients was 75 years, older than typical patients presenting with AAAs.[8] This likely reflects the increasing longevity of the population, the greater utilization of diagnostic imaging modalities such as CT or MRI, as well as the difficulty of detecting pelvic aneurysms until they have significantly enlarged. More than three quarters of patients had common iliac aneurysmal disease, and less than one quarter had isolated involvement of the internal iliac artery. Similarly, Richardson et al[2] noted that the common iliac artery is involved in about 70% of cases, the internal iliac artery in 20%, and the external iliac artery in the remaining 10%, with multiplicity of IAAs quite common.[2]

Mirroring the experience with AAAs, endovascular IAA repair affords the patient a host of short-term advantages compared with standard open surgical repair. The use of regional or local anesthesia in most repairs (62% in this series) allows patients with compromised pulmonary function to avoid general anesthesia. Mortality and morbidity is limited, and we observed no postoperative myocardial infarctions, pneumonias, or deaths. In addition, the transfemoral approach, often unilateral and frequently percutaneous, avoids the morbidity of conventional transperitoneal or retroperitoneal approaches, which are often complicated in the reoperative setting. These factors likely contributed to the short length of stay (mean, 1.3 days) noted in our study.

Early in our experience, contrast-enhanced CT and digital subtraction angiography were used routinely before endovascular repair, now we currently plan most interventions based on CTA alone, reserving angiography for tortuous and complex anatomy. CTA usually provides all necessary measurements of aneurysm extent and dimensions that are required for planning therapy. With the availability of several "off-the-shelf" stent-grafts, often as components of commercially available systems for endovascular AAA repair, IAA repair can now easily be performed in a single setting in most patients.

Several adjunctive technical strategies have to be used to achieve adequate iliac aneurysm exclusion and depend on the specific anatomy. No formal criteria of an adequate neck length exist for iliac aneurysms, but we adhered to a length similar to that suggested for endovascular aortic aneurysm repair, namely a 1.5-cm minimum length of nonaneurysmal, thrombus-free artery proximally and distally.[9] Patients with shorter necks tended to have extension of the aneurysmal process to or from the bifurcation, which in one case required conversion to a bifurcated device when a unilateral stent-graft was not able to seal proximally, despite the appearance of a 1-cm neck.

Bifurcated stent-grafts are required in the absence of an adequate proximal neck, but care should be used in avoiding a significant crowding of the two limbs of a bifurcated graft in a small, undilated aorta. In most cases, the aneurysmal process extended to or into the internal iliac artery. Under these circumstances, the origin of the internal iliac artery (or its branches, if the internal iliac artery is also aneurysmal) was coil-embolized before the stent-graft was deployed. Coil embolization of the internal iliac artery branches and origin with adjunctive stent-grafting was required for aneurysms of the internal iliac artery.

If both internal iliac arteries are involved in the aneurysm, some consideration may be given to preserving flow into one of the internal iliac arteries. Many strategies can be used, depending on the anatomy. We typically prefer a bypass to a preserved main trunk, if available, as is sometimes required with endovascular repair of complex aortoiliac aneurysms.[10] An endovascular aortouniiliac repair and contralateral external-to-internal iliac stent-graft may be feasible but was not used in any of the patients presented here.[11] On occasion, bilateral coiling may become necessary with extensive bilateral internal iliac aneurysms.[10,12] In the case of common IAAs extending to the internal iliac arteries, the development of branched stent-grafts suitable for deployment within the internal iliac artery may also reduce the incidence of pelvic ischemia in the future.

Even though 78% of patients in our series required internal iliac artery coil embolization, this should not be considered a uniformly benign procedure. No cases of colorectal ischemia or buttock necrosis were reported, but 23% (9/39) of those who required internal iliac artery exclusion (coiling or coverage) reported new-onset buttock claudication, similar to the 10% to 50% risk described by others.[10,12–14] This was transient in most cases, resolving within weeks, but several patients experienced symptoms for months to years, underscoring the potentially disabling nature of even "mild" pelvic ischemic symptoms. We did not observe a difference in the incidence of buttock claudication in patients undergoing branch-vessel vs main-trunk internal iliac artery coiling; however, embolization of distal internal iliac branches, as is required for internal IAAs and resulting in the interruption of pelvic collateral circulation, has been suggested to increase the risks of pelvic ischemic symptoms markedly.[10,12]

Endoleak type and incidence (13%) was similar to that reported after endovascular AAA repairs at 1 month.[15–18] Endoleaks after IAA repair were classified with the same type I to IV terminology applied in AAAs. Although these may have a different anatomic basis, type I and II endoleaks after IAA repair may also predispose to aneurysm rupture in the setting of IAA enlargement noted on follow-up surveillance. Type II endoleaks after IAA repair may be the result of missed branches not seen at the original time of branch embolization or persistent flow through branches despite the placement of coils.

Late occurrence of endoleaks was relatively more frequent in our series than that reported by others.[7,9,14] This may partially be explained by an aggressive stance in treating technically challenging cases and reporting even indeterminate situations as endoleaks. Notably, however, there were no obvious early or late type I endoleaks or ruptures, underscoring the feasibility of applying existing stent-grafts to the iliac anatomy.

When postoperative CTAs were examined, significant shrinkage did not occur in most of the patients until the 1-year time point. Fahrni et al[19] similarly found that in 19 patients who underwent endovascular IAA repair with mean follow-up of 21 months, aneurysm size remained unchanged in 74% (14/19). In contrast, in a study of 31 patients with mean follow-up of 31 months, Sahgal et al[9] noted a decrease in IAA diameter in all but one patient (97%) at a mean rate of 5 mm/year over the first year, slowing dramatically thereafter.

Interestingly, several of the patients in this series with longer follow-up were noted to have significant aneurysm shrinkage (Fig 5, *A* and *B*). Alternatively, the degree of aneurysm shrinkage, if any is expected, may be stent-graft dependent. The higher permeability of older Excluder (W. L. Gore & Assoc, Flagstaff, Ariz) components has been suggested as one explanation for the somewhat lower rate of IAA shrinkage overall. However, Excluder stent-grafts accounted for less than half of all components used (Table II). Graft-dependent changes in aneurysm diameter are difficult to deduce on the basis of this small series.

Since commercially available stent-grafts have become widely available, we have offered endovascular repair as an option to all anatomically appropriate patients with IAAs >3 to 4 cm in diameter. When both open and endovascular treatment was feasible, patients were advised of the risks and benefits of either option, including the possibility of claudication if internal iliac exclusion was performed. Few open repairs have been performed since 2001, reflecting mainly patient preference. Occasionally, younger patients reluctant to return for potentially lifelong radiographic follow-up or those wishing to avoid claudication associated with internal iliac artery coil embolization have chosen open repair.

The initial results of endovascular IAA repair in this study and others mirrors those of endovascular AAA repair.[7,9,14,19] Echoing the results of recently published randomized trials of endovascular vs open AAA repair,[5,6] the low perioperative mortality of endovascular IAA repair (0% in this series) challenges the early results of open surgery in even the most experienced hands.

Primary patency was high, but the 4.4% incidence of stent-graft thrombosis in this series was similar to that of aortic endografts extended to the external iliac artery,

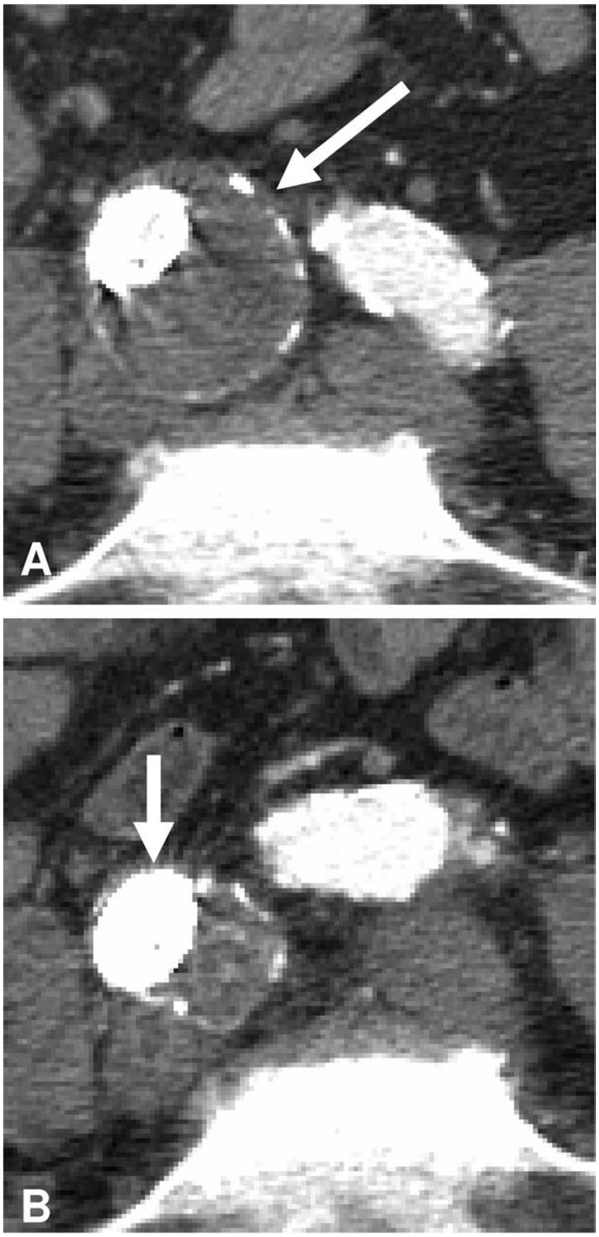

Fig 5. A 69-year-old patient with right common iliac artery aneurysm initially measuring 5.0 cm underwent endovascular repair. **A**, A computed tomography angiogram 1 month postoperatively shows the right common iliac artery aneurysm diameter has decreased to 4.2 cm *(arrow)*. **B**, By 3 years, the aneurysm measures only 2.4-cm *(arrow)*.

which is known to have a slightly higher risk of thrombosis.[20] Interestingly, adjunctive stents were not routinely used to eliminate kinking, infolding, or end-orifice impingement at the time of the initial stent-graft repair. These self-expanding stent-grafts were usually "ironed-out" after deployment with a balloon to ensure complete expansion and absence of kinking at all points along the stent-graft.

Although only 33 patients had 1-month follow-up CT data, many of the remaining patients had CT follow-up at 6, 12, 24, or 36 months to ensure stent-graft patency. Patency of stent-grafts was also assessed by physical examination (ie, presence of a femoral pulse) at documented follow-up visits in the office if a recent CT scan was unavailable. However, some patients unavailable for follow-up clearly may have unrecognized limb-thromboses. The overall 11% rate of secondary interventions was not insignificant, approximating that described in endovascular AAA repair, and remains the main drawback of this technique.[16,21]

CONCLUSION

Endovascular repair of isolated IAAs is safe and effective, with initial mid-term results similar to those after endovascular AAA repair. The low morbidity and mortality of endovascular IAA repair make it particularly well suited to patients with significant comorbidities, especially those with a history of aortic surgery. Although these encouraging results demonstrate acceptable mid-term graft patency with limited secondary interventions, larger studies with longer-term follow-up will be necessary to assess the durability of endovascular IAA repair and its possible broader applicability as first-line therapy.

AUTHOR CONTRIBUTIONS

Conception and design: TNB, SFS, FS, AC, LKM, EDD, MSM
Analysis and interpretation: TNB, FS, AC, LKM, EDD, MSM
Data collection: TNB, FS, AC, LKM, EDD, MSM
Writing the article: TNB, SFS, FS, AC, LKM, EDD, MSM
Critical revision of the article: TNB, LKM, MSM
Final approval of the article: TNB, SFS, FS, AC, LKM, EDD, MSM
Statistical analysis: TNB, FS, EDD, MSM
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Overall responsibility: TNB

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